



(Ives.)



From Ordinary Photograph of Chromo-Lithograph.



From Isochromatic Photograph.

IVES' PROCESS OF ISOCHROMATIC PHOTOGRAPHY.



ACTINISM.*

BY PROFESSOR CHARLES F. HIMES, PH.D.

Col. CHAS. H. BANES, Chairman of the Committee on Exhibitions introduced the lecturer with the following remarks :

LADIES AND GENTLEMEN :—It has been the earnest desire of those in charge of the preparations for this exhibition, to give it an educational character ; and they have sought by all means at their disposal to develop this feature to the fullest extent. One of the most useful and popular means which they have adopted to attain this object, is the present course of lectures upon topics appropriate to the place and the subject of the exhibition, and the Committee in charge of this work have been most fortunate in securing the co-operation of a number of eminent men of science.

I have great pleasure in introducing to you Prof. Charles F. Himes, of Dickinson College, who will lecture this evening on the subject of "Actinism."

Prof. HIMES spoke as follows :

LADIES AND GENTLEMEN :—The branch of science which considers the chemical changes produced by the action of light—named many years ago by Herschel, Actino-chemistry—has been so developed

* A lecture delivered at the International Electrical Exhibition, October 2, 1884.

within recent years, that it has won its way to recognition as a most important, as well as interesting field of investigation. But, apart from its intrinsic interest, there seems to be an especial appropriateness in its consideration at this time, and in this place. Electrical illumination has converted night into day upon your streets, has rendered your shopkeepers independent of sunlight; and it promises, also, by reason of its richness in those very rays that effect chemical changes, to render those who employ the actinic power of light equally independent of the variable and uncertain light of the sun.

Our treatment of the subject this evening must necessarily be controlled by the limited time at our disposal, and it has seemed to me that the most may be accomplished by adopting as a general plan, as indicated in the syllabus, first, a rapid survey of the leading facts, as they present themselves in the development of the science, and the illustration of these by typical experiments, and then a consideration of these, as far as possible, in their connection, as explained by the wave theory of light. Uniform treatment of the subject is almost as necessarily excluded as exhaustive treatment, and it will be found necessary to pass by features of the highest interest, and possibly of even greater importance than those presented, without even an allusion. Again, whilst photographic processes and manipulations, as such, do not constitute the subject for our consideration, we will find it convenient, and even necessary, at times to employ the terms and processes of photography; but we will do so only in so far as they may assist in the discussion of those general facts and principles that constitute the scientific basis of all photographic practice.

¹⁰The fact that a pure white compound of silver, called by the alchemists horn silver, by us silver chloride, darkens in the light, was the first observed chemical effect of light, and occupies, in this connection, the same place that the attractive power imparted to amber by friction occupies in the history of electrical science.

I have here, in a protected roll, a piece of paper, coated with a thin layer of this substance. I unroll it, as you see, in the mellow light of these incandescent lamps, without any precaution whatever. That light, comfortable as it is to the eye, is comparatively feeble in its effect upon silver chloride. But Mr. Knapp will expose it for a short time to the light of our arc lamp, and, that any effect produced may be more readily noticed, I will first cover it with this cardboard, with a design cut out of it, so that a portion of the paper will be com-

pletely protected, whilst the other portion will receive the full effect of the light, and we may thus have the advantage of the contrast. In giving this fact the prominence I do, as the first observed in this connection, I do not, of course, ignore the general observation of the effect of light upon animal and vegetable life. That forced itself upon the attention of man in all ages. The necessity of light for healthy animal and vegetable growth, for the production of color in the flower and bloom upon the fruit, of course could not be overlooked. But in all these cases the action of light is so complicated with so-called vital processes, controlled by so-called vital force, that there is scarcely a hint at its action *per se*. The darkening of this compound, noticed as well by miners in an ore of silver as by the alchemists in a laboratory preparation, was unique, in that it was entirely uncomplicated with mysterious vital processes, in that it was purely a laboratory experiment, that invited investigation by ordinary methods.

You notice now, as I uncover this paper, returned to me by Mr. Knapp, after exposure, as you have seen, to the light of the arc lamp, how the unprotected portion, represented by the design cut out of the cardboard, has been decidedly darkened. This has been accomplished in less than a minute. Any one conversant with photographic practice will understand what that means, and will be surprised at the wonderfully actinic power of this arc lamp. For this substance darkens but slowly in diffused sunlight. Now, just as the isolated observed fact in electricity awaited Gilbert to expand it into a branch of science, so this fact waited until, about a century ago, Scheele, the eminent Swedish chemist, undertook its systematic investigation, and did for actino-chemistry what Gilbert had done for electricity. He explained the change effected by light, *practically*, as we understand it to-day, as a separation of chlorine. But he did more. The query arose in his mind, whether all the rays of sunlight were equally effective. He investigated the problem experimentally. Availing himself of the beautiful discovery of Newton, he threw, by means of a prism, the particolored band of light called the spectrum upon the floor of the room, and in it placed powdered silver chloride. He found the effect greatest at the blue end. We have not sunlight at our disposal to repeat this experiment as he did; but we will avail ourselves of our arc light, which we have already tested as to its actinic power. The beautiful spectrum you now see upon the screen is similar to his. In it we will now test the actinism of the extreme ends—the blue and

the red portions. We will employ an ordinary photographic glass plate, sensitive to light, so that the result can be exhibited by the lantern upon the screen. But first, in this case, all our incandescent lamps must be turned off. The reason for this will be apparent as we proceed. Now, with the assistance of Mr. Knapp, as you see, one end of our plate is exposed behind one half of a stereoscopic negative in the red end of the spectrum, and now the other half is held in the same way in the blue end of the spectrum. The exposure in each case has not exceeded thirty seconds. I now pass the plate to the photographic assistant, to be developed, with the request that the developed plate be exhibited to us, in time, by means of the lantern upon the screen. Whilst we await the result I will consider some very natural queries that may have arisen. Why is this experiment conducted so differently from that of a moment ago? Why are the results not exhibited at once, as then? What is implied, in this connection, in the word "developed?" I would simply say, first, that not the slightest trace of the action of light would have been visible upon the plate just exposed, upon either end, even upon the closest and most careful examination. But, secondly, in response to proper chemical tests, called developers, an invisible effect, sometimes called a latent effect, or image, will become visible, that is, of course, if it has been produced.

It is the possibility of the production of such an invisible latent, but developable effect of the action of light that constitutes the grand discovery of Daguerre, a discovery that may well be regarded as the initial fact of modern photography, and one that renders Daguerre the central figure around which the facts in photographic history most naturally group themselves. In this statement I have no disposition to deny or detract from the merits of other investigators in this direction. After Scheele almost every chemist and physicist of eminence had experimented to some extent with compounds sensitive to light. Among them Davy, Wedgewood, Wollaston, Herschell, Niépce, Talbot and many others whose names we cannot even take time to recall. Many of these, or most of them indeed, worked much more scientifically than Daguerre; many of them had a great measure of success in some directions; but all efforts to fix an impression of the image formed in the camera obscura upon a sensitive surface were practically failures up to the time of Daguerre's discovery. It may, therefore, be allowable to give a more detailed account of it, in order to emphasize its historic prominence.

Daguerre was a scene painter in Paris, and an artist of considerable merit, and highly successful in his profession. About 1824 he was first seized with the infatuation to fix permanently the evanescent pictures of the camera, which he employed to assist him in his profession. Nothing already accomplished in that direction seems to have incited him, or encouraged him. How much he even knew of what had been done cannot be accurately stated, but this much can I think be said with certainty, that nothing already accomplished indicated in the remotest degree the possibility of discovery in the direction finally taken by him.

But now I am notified that our exposed plate is ready to be exhibited upon the screen, and we will have the opportunity to compare the effects of the red and blue ends of the spectrum upon it. We see in the picture upon the screen that there has been an impression upon that end of the plate. I do not recognize the picture* but what it may be matters not, it is the fact that an impression has been produced, that is the all-important fact for us. The photographic assistant informs us that this is the half exposed in the blue end, and now as he passes the other end into the lantern the blank upon the screen shows the absence of effect by the red rays.

[Thus Fig. 1 represents our stereoscopic negative, in which a diagram is substituted for the sake of simplicity, for the view from nature, and in Fig 2 we have the resulting positive at the blue end, and the blank at the red end.]

So far our experiment yields results identical with those of Scheele's with silver chloride. But these effects, as I have already stated, were invisible when the plate left us; they have only put in an appearance under a treatment called *development*. And now let us return to the history of the discovery of this developable effect. Some portions of it remind us of those little bits of embellishment often thrown around the history of science, as well as civil history. I would hesitate to give it had I not strongest ground for belief in its authenticity. No alchemist had ever gone to work at a more unpromising task than that Daguerre had imposed upon himself. As years rolled on the passion only took deeper hold upon him. In spite of utter failures and discouragement of all kinds, for years, in loneliness and in secrecy, suspected of mental weakness, even by his wife, he kept on in

* It was a negative of Luray Cave, by C. H. James.

the same line of experiment. Finally one of those accidents, that only strike men who work their way across their path, brought him most remarkable success. One of his methods, in brief, was to subject polished plates of silver to the vapor of iodine until they became coated with a creamy film of silver iodide, then to expose this surface to the image in the camera ; but always without the hoped-for effect. The plates thus exposed, were then stowed away in the rubbish closet until the supply was exhausted. They were then taken out, re-polished and re-exposed

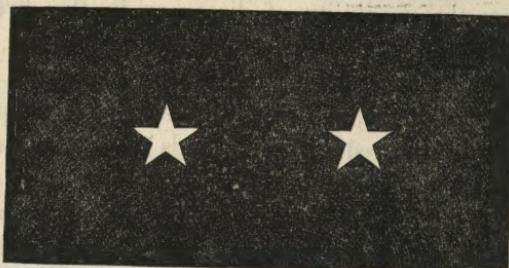
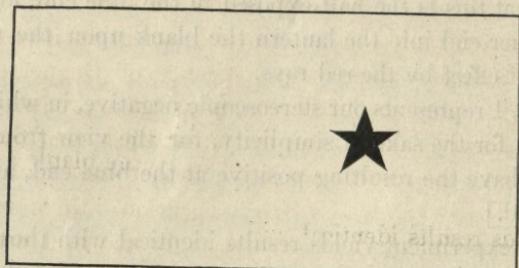


FIG. 1.



R.

FIG. 2.

B.

in the camera with the same discouraging results. Upon one occasion, on removal of the plate from the rubbish closet, he found upon it, to his great surprise, the very image that had fallen upon it in the camera. He proceeded to investigate. He exposed another plate in the camera and placed it in the closet with a similar result. Then exposing one plate after another in the camera, and each time removing from the closet some article before stowing the plate in it, each time he found upon it the same faithful delineation of his camera picture. At last everything had been removed, and still the exposed plate placed in the closet exhibited the developed image. Some mercury spilled upon the floor of the closet alone remained. The magician was detected. The vapor of mercury developed the invisible or latent image on the exposed

iodized plate. For some reason or other, the mercury adhered to the portions acted upon by the light, and in proportion to the action of the light, thus rendering faithfully all the gradation of tones. The excitement in the scientific world upon the announcement of the success was intense. Capital, however, hesitated to patronize the invention; but Arago struck with the exquisite beauty of these first Daguerreotypes, and the promises of the discovery, undertook its advocacy, and the French legislature pensioned Daguerre and his co-laborateur Niépce, that it might present the invention as a gift to the world. The formal announcement of the process was made before one of the most brilliant assemblages of the French capital. But it may be asked:—after all, what was there so important in the discovery of an invisible effect that needed development? The great value lay in the rapidity with which this developable effect could be produced. Hours required before to produce the feeblest visible effect were now reduced to minutes, and even seconds. It was permitted to hope that portraits would become possible. The first successful attempts at photographic portraiture were not, however, made by Daguerre, but by that remarkable man, Dr. John W. Draper,* of New York. By his previous careful scientific investigations, he was prepared at once to see the importance of Daguerre's discovery and to utilize it. But these compounds as then produced were comparatively so slow to receive even the latent effect, that the subject was obliged to sit with powdered face in the bright sunshine.

But to return to the spectrum. The recognition of three classes of effects in sunlight is inevitable. Two of these, light and heat, accompanied as they are by corresponding sensations report themselves to us directly. The existence of the third, without any corresponding sensation, we may regard as first established on a scientific basis by the investigations of Scheele, and he also showed that it was not equally distributed throughout the spectrum. Herschell in his investigation of the distribution of heat found, that after the visible spectrum had ceased with the extreme red rays, there were still rays invisible, incapable of affecting the retina, but capable of producing heat, and Professor Langley recently, with his delicate "bolometer," pushing his investigations still further into this infra-red region of the spectrum, has demonstrated the presence of rays where their presence was hardly suspected before, in fact where extra-polation formulæ would not allow them to exist.† So on the

* "Draper's Sci. Memoirs," p. 215; "Philosophical Magazine," Sept. 1840.

† "Am. Jour. Sci.," vol. xxvii, p. 170, March 1884.

other hand Ritter, continuing the investigations of Scheele, found equally invisible rays in the ultra-violet portion of the spectrum, capable in the highest degree of producing chemical changes.

The diagram now upon the screen (Fig. 3) is intended to exhibit the distribution of these qualities of sunlight in the spectrum in a most general way. Although liable to misinterpretation, with care, it will serve a purpose, and will help in emphasizing the direction in which some of the most recent advances in practical photography have been made. The curved line *III* shows the variation in the intensity of the heating effect, with its maximum in the dark infra-red region; the curved line *I*, shows the same for the luminous or visual effect, with its maximum near the line *D*, in the yellow, and gradually fading out at the limits of the visible spectrum; the curve *II*, is intended to show the distribution of actinism, with its maximum in the violet and extending far beyond into the ultra-violet dark space, but feeble in the visible portion, and almost wanting in the yellow, about the line *D*. This last may be regarded as correct for the compounds that have been and are yet generally used in photography; just as Scheele demonstrated for the

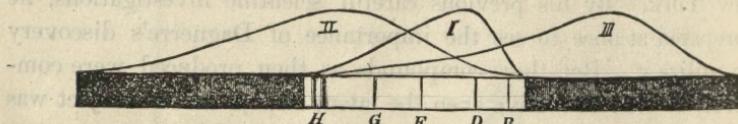


FIG. 3.

direct effect upon the silver chloride, and as we demonstrated a few moments ago for the developable effect upon others. We have in consequence become habituated to speak of violet as actinic rays, and of the red and yellow as non-actinic. We will find how incorrect this is.

It was demonstrated many years ago by Dr. Draper, among others, that the effective rays in producing those changes upon which vegetable growth depends are not the violet, or ultra-violet, not the photographic rays, but rather the yellow and orange. Even the compounds of silver in common use, on more careful investigation, display different degrees of sensitiveness to the different colored rays. The diagram now upon the screen, after Capt. Abney (Fig. 4), exhibits this fact in regard to the three closely related compounds, silver chloride, bromide, and iodide, the basis of modern photography. The upper diagram, you will recognize as a reference diagram of the solar spectrum, with the principal Fraunhofer lines, and the corresponding colors indicated beneath

Now following the curves indicating the variation in the intensity of effect upon the compounds, the maximum for each seems to be about at the same point in spectrum, about the line *G*, in the blue. But the variation in intensity from this maximum point is different in each case. On the iodide the diminution is very rapid toward the violet, as shown by the abrupt fall of the curve, whilst on the bromide it is very gradual, the colors from *b* to *H*, from green to violet, impress the bromide more nearly equally, and would therefore be much more uniformly rendered in a photograph upon it. But there is another fact equally apparent in the diagram, the range of effect upon the bromide is greater, as is shown by the extent of the curve beyond *b* on the one hand, and *H* on the other. The bromide would receive, then, impression from colors to which the others would be insensitive. But in spite of these marked differences, the rays toward the blue end are in each case the most effective. It seemed to be generally accepted for a long time that whilst an actinic effect of some degree could be produced throughout the whole visible spectrum, that whilst every ray that can affect the retina is also capable of affecting to some extent these sensitive compounds, still the power to produce chemical change resided, for some reason, in the highest degree, for all compounds, in the more refrangible rays toward the violet.

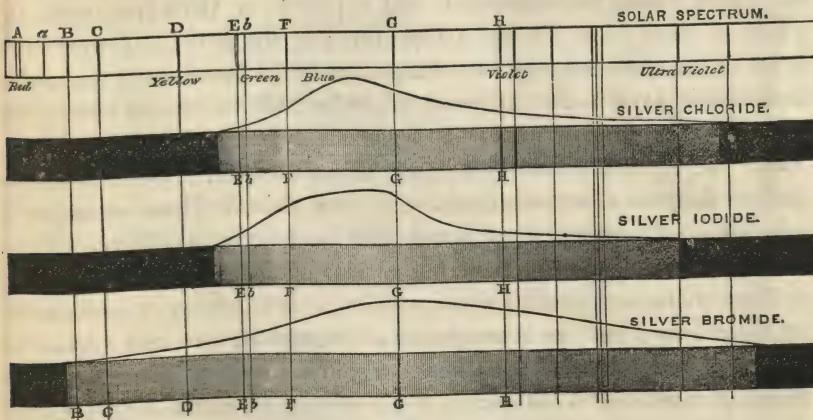


FIG. 4.

It seemed to be accepted almost as inevitable, that photography could never render faithfully the luminous or visual effects, the intensity of effect upon the retina, of the different colored portions of an

object, by proper shades in monochrome. That, for example, in a photograph of an orange tree, its bright yellow fruit, and its dark green leaves, would both be represented as equally dark, because practically equally non-actinic. So in the investigation of the spectrum by the aid of photography, that the actinic end alone would impress itself with all its details, and that for the infra-red, other modes of investigation would have to be resorted to. Directed by a theory, which we will notice presently, Dr. H. W. Vogel,* of Berlin, succeeded, in 1873, in increasing the sensitiveness of these same common compounds of photography to the less refrangible, non-actinic rays. The process is so simple that it surprises. The light that acts chemically is the light that is absorbed by the particular substance, or, light to produce an effect must be absorbed. This condition was first enunciated and demonstrated by Dr. Draper.† Dr. Vogel stained the sensitive film with some transparent dye. That certainly meant absorption of certain selected rays; of the red, if he pleased so to select the dye. Just as the blue glass, which I now place in front of our arc-light, absorbs certain rays, and cuts them out of the spectrum upon the screen, as you see. (See Fig. 7.) He reasoned, then, that these absorbed rays may become photographically effective, and produce, or increase the intensity of, the impression upon the sensitive compound. If red was absorbed the effect of the red portions of an object would be heightened, and approach, or perhaps equal, the effect of other more directly actinic rays; or the point of maximum effect in the spectrum might be changed, and rays previously altogether non-actinic, even in the infra-red, might be made to report themselves upon the photographic plate. It is not necessary to indorse this theory. There are, it must be confessed, grave objections to it. But the accomplished fact must be recognized by all, that stained films sensitive to rays commonly regarded as non-actinic have been produced. Capt. Abney,‡ by a different method, has also modified the bromide of silver, without changing its chemical composition, so as to render it impervious by the red rays, and has succeeded in photographing the red end of the spectrum. But Dr. H. W. Vogel,§ within the last few months, as the result of continued investigation in his original direction, has achieved a success in practical photography which, in its results, seems only second

* See foot-note p. 355.

† "Draper's Sci. Memoirs," p. 230; "Philos. Mag.," Sept., 1841, p. 435.

‡ "Chem. Effect of Spectrum." Eder, p. 49.

§ See foot-note p. 355.

to that of Daguerre, and which leaves nothing great beyond to be accomplished, except the fixing of the colors themselves. A new word is necessary to describe this phase of the art. The term isochromatic photography has been introduced. A photography that will give you a picture of the orange tree with its yellow fruit and green leaves, not in their natural colors, but what is almost as desirable, in their natural shades, according to their luminous or visual intensity, the intensity of the impression they make upon the retina of the eye. A photograph of an oil painting, by the old process, could not but be unsatisfactory. Its yellows would be dark, its warm reds would be black, whilst its deep blues, that hardly affect the eye, would present themselves among the high lights of the picture. By the isochromatic process the reds, yellows and blues of the painting are all represented by shades that faithfully represent their luminous or visual effect. An artist whose pictures have been copied by it expresses himself as fully satisfied with the results, which is certainly a very valuable indorsement. Prof. Vogel claims to be able to produce eightfold the effect by yellow light that is produced by blue light. From the dye employed it is spoken of as the azaline process. What an advance since the days of Scheele, or even of Daguerre !*

* The term orthochromatic has been proposed by Dr. Eder, and is growing into use, instead of isochromatic, since it is equally descriptive of the peculiarity of the new process, and is free from confusion due to previous use in a different connection. The increasing interest in this process, and its expansion into a commercial one, for orthochromatic plates are advertised for sale, call for a somewhat fuller notice in regard to it. The credit of having directed investigations into this channel unquestionably belongs to Dr. Vogel. In 1873 (*Philadelphia Photographer*, vol. ii, p. 25, Jan., 1874; *Photographische Mittheilung*, 1873; *Photographic News*, 1874), in experimenting upon alkaline development on silver bromide dry plates, with the spectrum, he found in certain cases unusual sensitiveness to the so-called non-actinic rays. By careful investigation he traced this to the preservative, or other coating of the plate. He had previously enunciated as a law that a sensitizer should be capable of acting as an absorbent of the liberated halogen, and, at the same time, of the light which acts photographically, or, that chemical and optical absorption should accompany each other. Directed by this, by dyeing the film with coraline, he produced plates sensitive to yellow, and, by the use of an aniline-green, plates highly sensitive to red, and concluded that silver bromide could be rendered sensitive to any color. A picture of a blue ribbon on a yellow ground, which by the ordinary process was white on a dark ground, by his process was dark on a light ground. It was necessary to put a yellow glass in front of the lens to tone down the blue, otherwise, if both colors were of equal actinic effect, no

[In the absence of an illustration by Dr. Vogel's process, we are fortunate to have placed at our disposal, since the delivery of the lecture, one by Mr. F. E. Ives of Philadelphia, by his myrtle-chlorophyl

contrast would have been obtained. In these earlier cases sensitiveness to some particular selected color seems to have been secured rather than equal sensitiveness to all colors. Eosine, suggested afterward by Major Waterhouse, was employed with better success, and Dr. Vogel's continued investigations led to his perfected isochromatic process, in which azaline was employed, in 1884 (*Philadelphia Photographer*, Aug., 1884, p. 251; *Id. Sept.*, p. 284). Results by this process of the most varied character on exhibition at the New Orleans International Exhibition are pronounced "marvelous" (*Photo. Times*, Feb. 27, 1885). The announcement of the effect of dyes for this purpose by Vogel was followed by experiments in the same direction by Abney, Waterhouse, Lea and others, and whilst his theory of optical sensitizers was not accepted, nor in all cases could the precise results obtained by Vogel be reproduced, the demonstration of the possibility of isochromatic effects in this way is conceded to him. Dyed films were undoubtedly suggested and used by M. Carey Lea prior to their employment by Vogel (*Anthony's Phot. Bulletin*, Jan. 10, 1885, p. 6; *Stillman's Am. Jour. Sci.*, Jan. 1885, p. 53), but for an entirely different purpose (the prevention of blurring), and without noticing any sensitizing effect to non-actinic rays, if any occurred, and without even hinting at any such possible effect of the dye. It has recently been shown by Lea (*Ibid.*) that the haloid salts of silver are capable of forming compounds with some coloring matters similar to lakes, by use of which plates sensitive to color may be prepared. This seems to be in accord with Abney's theory, that the increased sensitiveness to color is due to the formation of compounds in Vogel's experiments (*Chem. Effects of Spectrum*, Eder, p. 39). In 1879, F. E. Ives, of Philadelphia (*Philad. Photographer*, Dec., 1879, p. 365), published a process in all its details, in which chlorophyl obtained from the leaves of the blue myrtle was employed as the dye, and a cell with glass sides containing a solution of bichromate of potash was substituted for the yellow glass of Vogel. The former has the advantage that the strength of the solution can be readily adapted to the quality of the plate and the character of the subject. He lays great stress upon the chlorophyl from this particular plant, and prepared according to his method, and claims that it was the first perfected isochromatic process, and even unequalled in its results by Vogel's azaline process, which it antedates several years. The specimen by his process herewith presented (see frontispiece) certainly exhibits wonderful capabilities of the process. Béquerel, in 1875 (*Chem. Effect of Spectrum*, Eder, p. 41; from *Comp. Rend.*, vol. lxxix, p. 189), found that chlorophyl acted as a sensitizer to the non-actinic rays. Isochromatic plates by any process are slower than ordinary plates, and the yellow screen seems necessary to tone down the blue, but they are susceptible of many applications peculiarly their own. They have been suggested for copying old manuscripts as well as oil paintings.

process first published in 1879,* and in which we are at a loss which to admire most, the isochromatic effect, or the exquisite photo-typographic prints, made by the well known process of the same gentleman. The subject was a highly colored chromo-lithograph of a lady, wearing a bright scarlet hat with purple feather, a yellow-brown cape, and a dark-blue dress. The effect of the non-actinic colors has been even exaggerated, purposely, to demonstrate the capacity of the process.]

What is the nature of the changes produced by light? Scheele demonstrated, if he did not express it in the terms that we employ to-day, that silver chloride was decomposed by the action of light, that its rays dissected off atoms of chlorine, or to use a more modern term that it was a case of chemical *dissociation*, and that a lower chloride of silver was formed of a violet color. With reference to the effect, subsequently discovered, upon bromide and iodide of silver, opinion was at first inclined to call the change a physical one, and not chemical, a change in the arrangement of the molecules of the substance, in their relations to each other, not a change in their kind; afterward opinion was divided between physical and chemical change, whilst to-day there is general agreement that the change is essentially the same as that experienced by the chloride, namely chemical dissociation or decomposition, that bromine and iodine are separated. The difference between the chloride and iodide, or bromide, lies in the fact, also first clearly stated by Professor Vogel,† that the latter demand, as a favoring condition, that something should be present to dispose of, to absorb, the liberated iodine or bromine.

Indeed iodide of silver, without the presence of some such an absorbent, is not acted upon by light, and the bromide but slightly. A photographic collodion plate always contains such an absorbent in the free silver nitrate solution adhering to it. If an iodized sensitive plate is thoroughly washed, it becomes insensitive, but if now it be dipped into a solution of tannin it becomes sensitive, even when dried. Tannin acts as an organic absorbent of iodine. Photographic collodion dry plates rest upon the presence of such chemical absorbents, as sensitizers, and which from their action we called *chemical sensitizers*. To the sensitizers, previously described, that render isochromatic photography possible, the dyes applied to the film, the name *optical sensitizers* has been given by Dr. Vogel, on the ground that they do

* See foot-note p. 355.

† "Photographic News," 1865, p. 209.

not act chemically, or as absorbents of iodine, or to state him more fully, because there is considerable discussion going on at this point, they do not act exclusively or principally as chemical absorbents, but by reason of their power to absorb particular colored rays, and thus to increase their effect by increasing the quantity, so to speak, of that particular light acting upon the chemical compound with which they are associated.

I confess there are difficulties, theoretical and practical, in the way of accepting this theory of optical sensitizers, but it does not minify the discovery of Dr. Vogel to disagree with him on this point, and so eminent an authority as Captain Abney rejects altogether the term optical sensitizer, and as already stated, he has succeeded in photographing the red end of the spectrum by modifying the silver bromide, upon an entirely different plan.*

There is another very remarkable actinic effect that calls for a passing notice. It might be inferred, that if the action of light for a short time produces these feeble but developable effects, the action for a longer time would increase the effect, that a photographic plate exposed to a view in the camera would only give a more easily developed impression the longer the exposure. It is true that the number of molecules decomposed is proportional to the action of the light, that light does all the work of decomposition, that one decomposed molecule does not propagate, so to speak, the effect to others, but still it is a fact well known to photographers, and generally called *solarization*, that a reversed effect is produced upon a plate exposed for too long a time; that on such a plate, the sky, for example, the high light of the picture, that should produce the most intense effect, that should darken most under development in the negative, becomes thin and transparent. And in photographing the solar spectrum it is possible to produce these reversed effects, so that the dark lines receive a heavier deposit, and instead of being transparent in the negative, as might be expected, are more opaque than the luminous portions of the spectrum. A slight previous exposure of the plate to diffused daylight, before exposing in the camera, is favorable to this reversion of effect.

We can only say that one explanation of this contradictory phenomenon is, that there is an oxidizing action of the rays subsequent to the first effect of decomposition, and this brings us now to notice a

* Chemical Effect of Spectrum, Eder, p. 49.

radically different class of effects of light from those that we have been considering. I have here upon the table, protected from the light by a slight covering, a series of little glass bulbs such as I hold in my hand, with tubes at each side, connected with each other by gum tubing, and finally with a glass tube leading out through the cork of a glass flask, or decomposing cell, which contains hydrochloric acid. Into this, through holes in the cork, protected by glass tubes, dip carbon rods, the flask being closed air-tight. The carbon rods are connected with the poles of the battery upon the table. The current of electricity passing through the hydrochloric acid, as is well known, separates the elements of which it is composed, and the hydrogen and chlorine pass out through these bulbs non-combined, but simply mixed as gases, and after a time these bulbs will be filled with a mixture of the gases in the proportions in which they were present in the hydrochloric acid. Now, singular to say, what the electricity has done light can undo, or *vice versa*. I place one of these little globes, containing the mixed gases, with the end of one tube underneath the colored liquid in this little bottle, whilst the other tube is tightly closed. I now turn on this incandescent light near the bulb, the rise of liquid into the bulb shows that the gases have combined to that extent, and that the resulting compound, the hydrochloric acid formed has been absorbed by the liquid. The rapidity of the combination depends upon the actinic intensity of the light. If placed in sunlight, or even the glare of the arc-light, they would combine with explosive rapidity, and we would fail to follow the experiment as we can in this way. Now this combining action of light upon hydrogen and chlorine is distributed throughout the spectrum in the same manner as the dissociating action upon silver chloride. If we could determine the degree of one kind of effect produced by a given light, we would have determined it for the other.

I have selected this experiment, and have performed it as I have, to assist in illustrating one of the various methods for measuring the actinic intensity of light. The effect upon the eye, the photometric effect, does not afford any means of judging of actinic effect. As we have seen, the rays that effect the retina have feeble actinic effect; it is in most cases the invisible rays that do the photographic work. Now the quality of sunlight in this respect varies from day to day and hour to hour, as well as with the seasons, with meteoric conditions that do not report themselves to the eye, or to ordinary meteoro-

logical instruments. Nothing could be more desirable to those employing this agency, than some method, or instrument rather, by which actinic intensity of sunlight could be readily tested at any time.

That remarkable man, Dr. John W. Draper, of New York, who never simply did a little and suggested a great deal more for some one else to do, as is so often the case, first used this fact of the combination of hydrogen and chlorine under the action of light for actinometric purposes.* He devised an instrument, and made determinations of surprising accuracy, and Bunsen and Roscoe† long afterwards adopted his plan and expanded it so as to establish *actinometry* on a thoroughly scientific basis.

I call your attention now, by way of illustration of one mode of application of these facts, to a piece of apparatus, devised by Dufour,‡ in which this apparent antagonism between the electrical current and actinism is utilized for measuring the latter. In the diagram (Fig. 5)

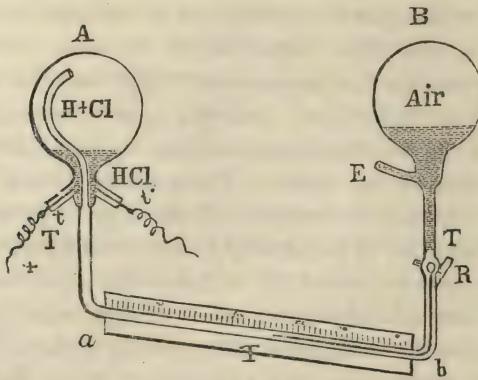


FIG. 5.

A and *B* are glass bulbs connected by a small glass tube *T*, *T*, *T*, which passes up through the neck of *A*, as indicated, and opens into the bulb near the top. This bulb is partially filled with hydrochloric acid, *HCl*, with a mixture of hydrogen and chlorine gases, *H* + *Cl*, sensitive to light above. In the other bulb *B*, an equal volume of air is enclosed over sulphuric acid. The stop-cock at *R* being opened, the sulphuric acid

* "Draper's Memoirs," p. 245; "American Jour. Sci.," vol. xlvi; "Philos. Mag.," Dec. 1843.

† "Die Actinometrie, Pizzighelli," p. 13; "Poggendorff Annalen," Vol. c., pp. 43, 481; "Watts Dict. of Chem.," Vol. iii, p. 678.

‡ "Die Actinometrie, Pizzighelli," p. 37; "Photo. News," 1881, p. 158.

will take a fixed position in the horizontal graduated connecting tube, and serve as an index. Now upon exposure of the bulbs to light, a portion of the gaseous mixture in *A*, would combine, and the resulting hydrochloric acid gas formed would be at once absorbed by the liquid, and the sulphuric acid index would move toward *A*. Any disturbing influence of heat upon the experiment is eliminated by the equality of effect on both bulbs. But now, if instead of simply allowing light to produce combination, we at the same time produce a counter effect by means of an electrical current passed through the *HCl*, by means of small carbon rods inserted through the lateral tubes *t*, *t*, and connected with the poles of a battery, by varying the current until combination and decomposition are equal, the index will be rendered stationary and a comparison of the strength of electrical currents required in two cases to produce this condition will be a comparison of the actinism of the light in any two cases. It is almost needless to remind you that there are many substances adapted to actinometric purposes. Silver chloride paper, such as we used in our first experiment has been employed. Ferric oxalate, which, under the influence of light, decomposes and evolves carbon dioxide, which may be measured or estimated by loss, was also suggested and used by Dr. Draper. But there is still need of a convenient and reliable actinometric method. But in any case it is plain from what we have already said that an actinometer adapted to one set of rays would not be reliable for others; or one that would give the intensity of effect at a given time upon one substance would not necessarily give the effect upon another substance.

We have thus rapidly noticed some of the leading actinic effects of light. How are these effects produced? This question brings us face to face with the other questions: What is the mechanism of light? What is the ultimate constitution of matter? We have no difficulty in accepting the undulatory theory of light so clearly set forth by Sir William Thomson* a few days ago. Let us assume in round numbers that 800 million million of undulations per second of the hypothetical ether, that pervades all space and all matter, produces the sensation of violet and 400 million million produce that of red; that beyond violet there are other undulations still more rapid, and below red slower ones, neither of which report themselves to us as light, that do not affect the retina of the eye. These wavelets beat upon the sensitive compounds we

* Lecture on "Wave Theory of Light," Academy of Music. *Vide this JOURNAL, Nov. 1884.*

have been considering; these are composed of groups of atoms called molecules; these molecules are shaken until each one loses an atom or two, new groups of atoms, new molecules are formed, that is a new substance is formed. It may have a color different from that of the original, perhaps, as sub-chloride of silver, or different attractive properties, as the changed iodide for mercury in Daguerre's process, or for silver just reduced from its solution as in the ordinary collodion process. We are surprised sometimes at the rapidity of the action of light at the so-called instantaneous photographic effects; the pictures of animals in motion, of bombs bursting in air, etc. Let us look at these in the light of our theory, and may be we will find that after all these effects are rather slow. I now call your attention to a photograph upon the screen, of sparks of a Holtz machine (Fig. 6.). I have selected

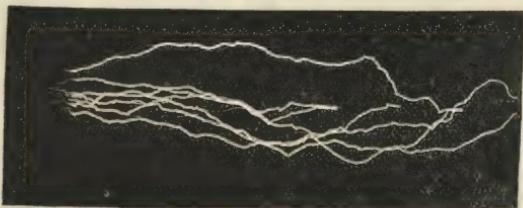


FIG. 6.

this because these sparks are of shorter duration than that any instantaneous drop or slide could be made to give. They impressed themselves upon an ordinary collodion plate in the camera as they passed. Suppose we assume $\frac{1}{20000}$ th of a second as the time, and we will certainly be within bounds. That is a fraction difficult to comprehend. Sir William Thomson* told you a few days ago, that it was easy to understand large numbers, just as easy to comprehend a million-million as a million, that it is the negation of infinity that is difficult to understand. But this small fraction will trouble us. Our mental dividing engine fails in performance as we work toward zero. The twenty-thousandth of a second is so small that it eludes our mental grasp. Now astronomers when wrestling with celestial distances frequently resort to artifices to bring them within the range of comprehension. They fire imaginary cannon balls at the sun, and convert the vast distance into time by calculating the duration of its flight at its greatest

* Lecture at Academy of Music, Sept. 29th. *Vide this JOURNAL, Nov. 1884, vol. cxviii, p. 327.*

velocity ; again they build imaginary railroads to the fixed stars, and calculate the generations that will be born and perish before the train reaches its destination, or to bring the matter down still nearer the ordinary apprehension, they calculate the fare and state it in terms of the national blessing as a unit, and thus put it on a dollar and cent basis, and we allow ourselves to be persuaded that we have mastered the difficulty. Now without resorting to any artifice, without changing the character of our phenomenon, but simply looking at it from another point of view, let us regard the effect as a space effect of light instead of a time effect. Light has a velocity in round numbers of 190,000 miles per second, that would be 190 miles in one thousandth of a second, 19 in one ten-thousandth, or say 10 miles in our $\frac{1}{20000}$ th of a second. Ten miles of light drive in upon our plate in that time; or if we held the corpuscular theory of light of Newton, a chain of these little pellets ten miles long would have delivered themselves upon the sensitive surfaces. Ten miles is comprehensible, one mile is, so that we could easily conceive of an effect in one-tenth of the time allowed to our electric sparks. But let us take another look at it. Light is not corpuscles but undulations, tiny wavelets, ripples of ether, 800 million-million in a second for violet, a number we can easily understand, as Sir William Thomson has told us; that would make 800 thousand-million in one thousandth, eighty thousand-million in one ten-thousandth, or 40,000 million impulses striking upon our sensitive molecules in our $\frac{1}{20000}$ th of a second. Surely that number should produce an effect. We can readily conceive that one thousand-million wavelets might produce an appreciable effect. They would only represent one eight-hundred-thousandth of a second, say one millionth of a second. That would seem, then, to be ample time to produce a photographic effect. Theoretically, we would hardly fix it as a limit of photographic sensitiveness, an encouragement certainly to instantaneous photography ; for although the light of the sparks was and intense, the waves sent out by it have great amplitude, the plate that they have impressed is comparatively insensitive, not such as we would employ ordinarily to receive an instantaneous impression.

But it may be said these wavelets are very small, but so are the portions of matter upon which they operate, molecules that not only elude our grasp, but almost defy calculation, and still smaller atoms, the components of these molecules. The action of these waves of light upon matter may not, unfitly, then be compared to that of the

waves of the ocean upon the shore. But to get some notion of how these wavelets may act, let us resort to a coarse mechanical contrivance that will exhibit transfer of energy. These two balls, or pendulums, are connected, by suspension, on this wire stretched across the stage. I cause the one to vibrate, you notice that the other ball soon begins to vibrate, and also that its motion increases. Now if you turn your attention to the first, you will notice that its motion is decreasing at the same rate that that of the second is increasing. Now the second has acquired all the motion of the first, the first has ceased moving, and now the motion begins to be returned by the second to the first. I have arranged these balls so that either is, so to speak, in a peculiarly receptive condition with reference to the motion of the other. They are pendulums of equal lengths, of the same periods of vibration. I now change the length of one, by sliding the second ball upward on its supporting cord. I vibrate the first again, the second as you see takes motion again; the first looses, but for a much shorter time, and in a much smaller degree. Our second ball fails to take all the motion from the first. It is not as receptive as it was before. By similar experiments with this cord, containing two balls, by varying the positions of the balls, we see that there is a jarring of the combination, a movement very dissimilar to that of our two balls at first.

Now a luminous body transmits energy through the ether as a medium, as these balls do through the wire. The molecules of matter, composed of atoms of different kinds, may be in a receptive condition for vibrations of ether of a certain frequency, or they may be jarred, as it were, by these vibrations; atoms, or even groups of atoms, within the molecule may recognize their periods of vibration, and take up motion to such a degree as even to be thrown out. We can thus conceive of many ways in which molecular disruption could be brought about, which would mean chemical change.

But there is another phenomenon, beautiful in itself, and not only closely related to the subject in hand, but that seems to form a sort of a stepping-stone from this gross mechanical illustration to the actinic effect upon molecules. I have said that in this spectrum on the screen, far beyond the violet, there is a region of chemical activity but of darkness, where the photographic plate is impressed long after the retina ceases to be affected. Now if I were to pass out into this dark ultra-violet space, this paper, coated with sulphate of quinine, or other suitable substance, it would become visible, would *fluoresce*, would take

up these rapid vibrations of ether, and in some way render them visible, or, to express it better, would cause them to produce a visible effect.

Without taking time to perform the experiment in this way, because from the feebleness of the light it would be unsatisfactory to you, I will get an abundance of these rays by another method. This blue glass, that absorbs almost totally the other rays, allows these ultra-violet rays to pass. As I insert it in the path of the light that passes through the prism you see what portion of the spectrum it transmits. I now place this glass, before the arc light (by opening a side door of the lantern), and it casts only a deep blue, feebly luminous illumination upon the objects behind us. Now, whilst Mr. Knapp holds the blue glass in position, you notice that this white cardboard appears of a deep, feebly-luminous, blue. I now dip my brush into a solution of sulphate of quinine, and as I draw upon the card with the brush, you see how the tracings of the brush spring out in beautiful visible lines upon the dark-blue background of the card. The quinine solution reveals the presence of these ultra-violet rays; it somehow drags these rays down from the invisible into the visible portion of the spectrum, brings them within the range of retinal effect.

But now, what is equally surprising, though on reflection it is what we should expect, when the quinine brings these rays within the range of vision, it in so far removes them from the actinic field. In so far as they are made to affect the retina, in so far they cease to affect the sensitive plate. A photograph of this card, as it now appears in this ultra-violet light, with its luminous tracings of the brush, would give you dark letters upon a white ground, just as if drawn with ink; not as dark as with ink, but still deeply shaded, as they have been photographically degraded below the ultra-violet ground on which they are formed.

We have upon the wall much larger designs, kindly placed at my disposal by Professor Henry Morton, so well known in your city, of the Stevens Institute, of Hoboken. The two floral designs upon my left are of especial interest. The one is traced with thallene, a fluorescent substance, first isolated by Professor Morton; the other is formed of yellow paper. In the light of our electric arc lamp the paper design is most decided. We now illuminate with our ultra-violet light, by interposing the same blue glass; the thallene design springs out in beauty from the dark ground, by degrading the light into the region of vision; the paper design becomes almost invisible, having only the feebly luminous blue light to reflect. Briefly, what is the explanation

